# 操作系统原理及应用

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# Chapter 3 Processes

# Outline

- Process Concept
- Process Scheduling
- Operations on Processes
- Interprocess Communication
- Communication in Client-Server Systems

# Process Concept

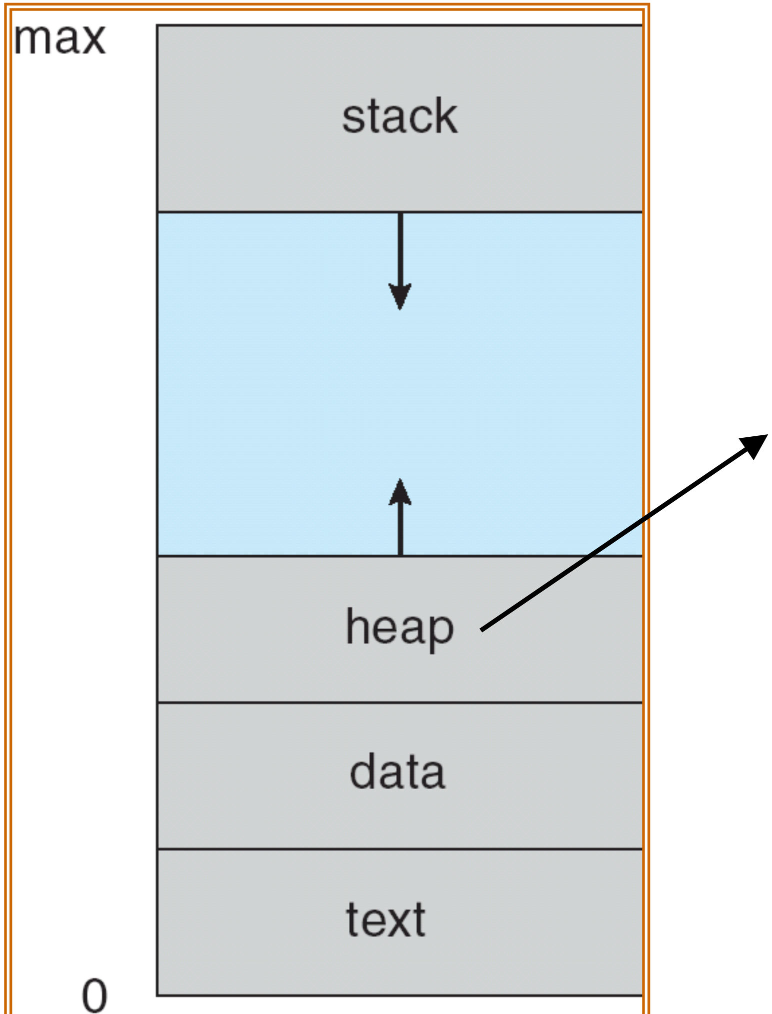
- **An operating system executes a variety of programs**
  - **Batch system – jobs**
  - **Time-shared systems – user programs or tasks**
- **Textbook uses the terms *job* and *process* almost interchangeably.**

# Process Concept

- **Process – a program in execution; process execution must progress in sequential fashion.**
- **A process includes**
  - **text section (program code)**
  - **program counter**
  - **contents of the processor's registers**
  - **Heap-stack — temporary data (function parameters, return address, local variables)**
  - **data section — global variables**

**current activity**

# Process in Memory




**Heap (堆) is memory that is dynamically allocated during process run time.**

# Process in Memory

```
//main.cpp
int a = 0;              ← 数据段
char *p1;               ← 数据段
main()
{   int b;              ← 栈
    char s[] = "abc";   ← 栈
    char *p2;           ← 栈
    char *p3 = "123456";   ← 栈
    p1 = (char *)malloc(10);   ← 堆
    p2 = (char *)malloc(20);   ← 堆
}
```

# Characteristic of Process

- **Dynamic (动态性)**
- **Independency (独立性)**
- **Concurrence (并发性)**
- **Structure (结构化)**

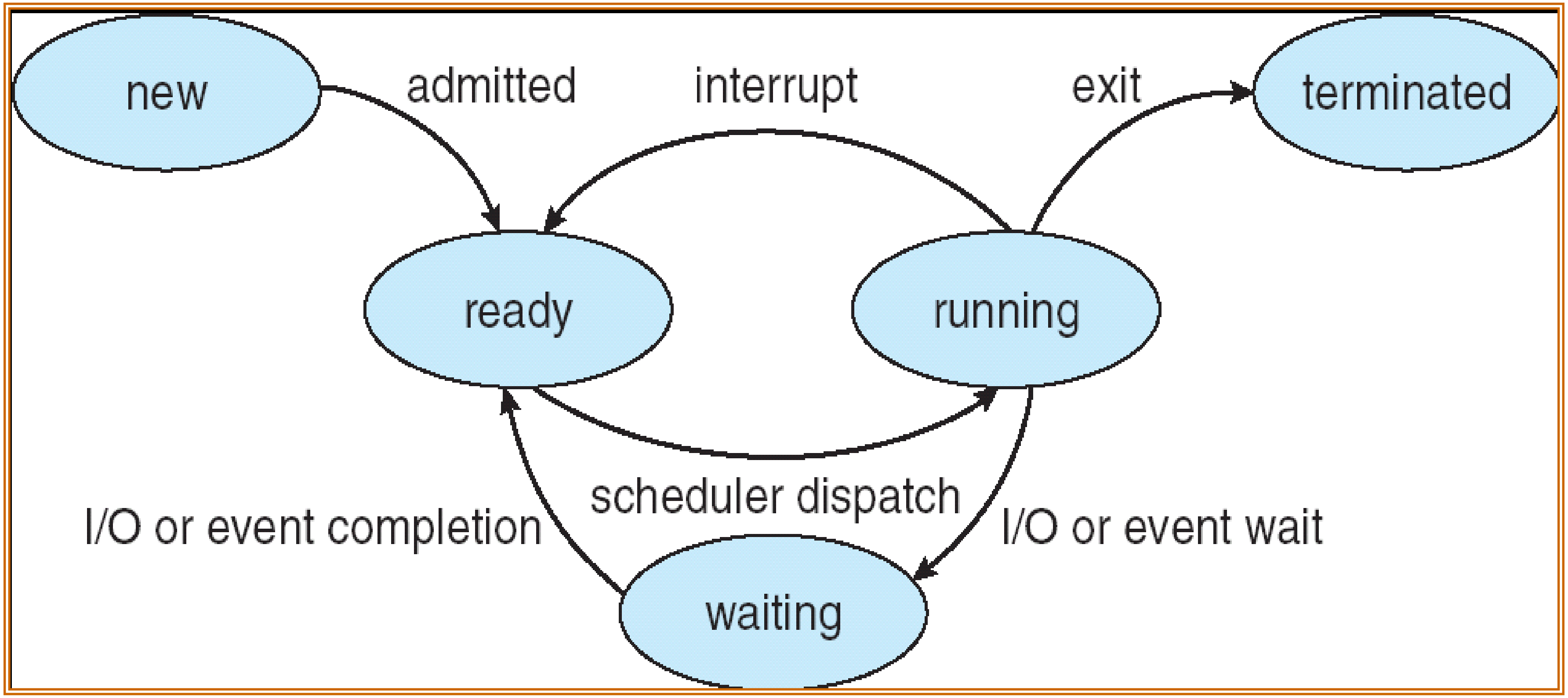
# 作业1

进程和程序是两个密切相关的概念，请阐述它们之间的区别和联系。

# Process State

- As a process executes, it changes *state*
  - **New**: The process is being created.
  - **Ready**: The process is waiting to be assigned to a processor.
  - **Running**: Instructions are being executed.
  - **Waiting**: The process is waiting for some event to occur.
  - **Terminated**: The process has finished execution.

# Diagram of Process State



# Exercise

- 在一个只有单处理机（不考虑多核）的操作系统中，进程有运行、就绪、等待三个基本状态。假如某时刻该系统中有10个用户进程并发执行，且CPU为非核心态情况下，试问：
  - 这时刻系统中处于运行状态的用户进程数最多有几个？最少有几个？
  - 这时刻系统中处于就绪状态的用户进程数最多有几个？最少有几个？
  - 这时刻系统中处于等待状态的用户进程数最多有几个？最少有几个？

# 作业2

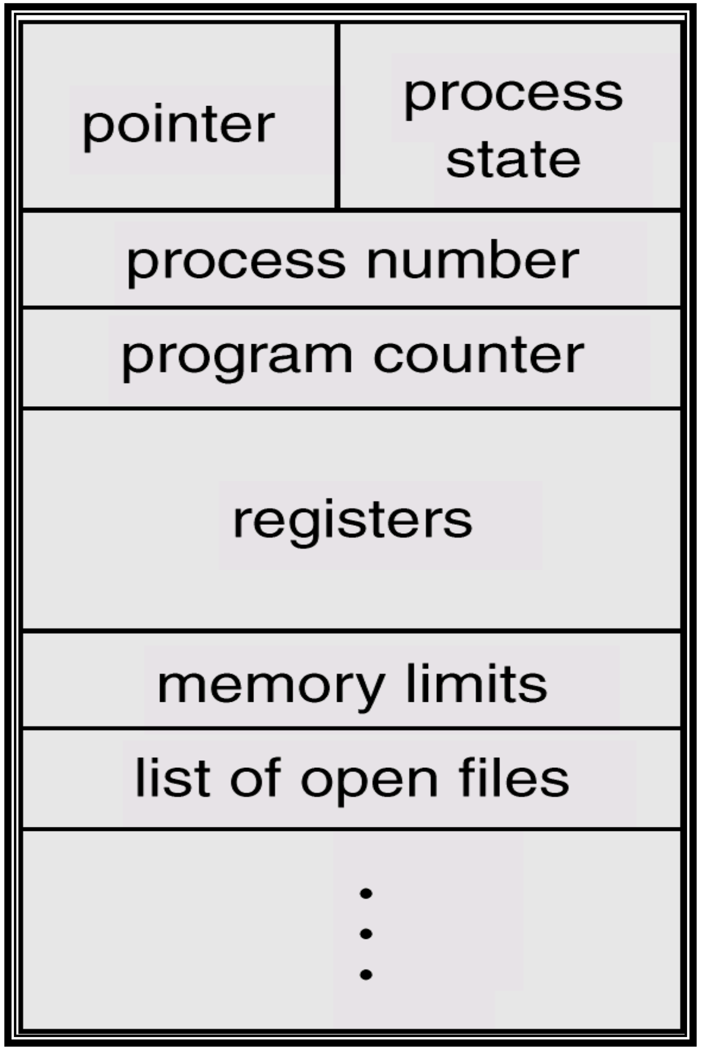
画出进程在就绪、运行和等待三个基本状态之间的状态转换图，并简述发生相应状态转换的原因。

# Process Control Block (PCB)

- Containing the information associated with a specific process
  - Process state
  - Program counter
  - CPU registers
  - CPU scheduling information
  - Memory-management information
  - Accounting information
  - I/O status information
  - … …

Must be saved when an interrupt occurs

# Process Control Block (PCB)



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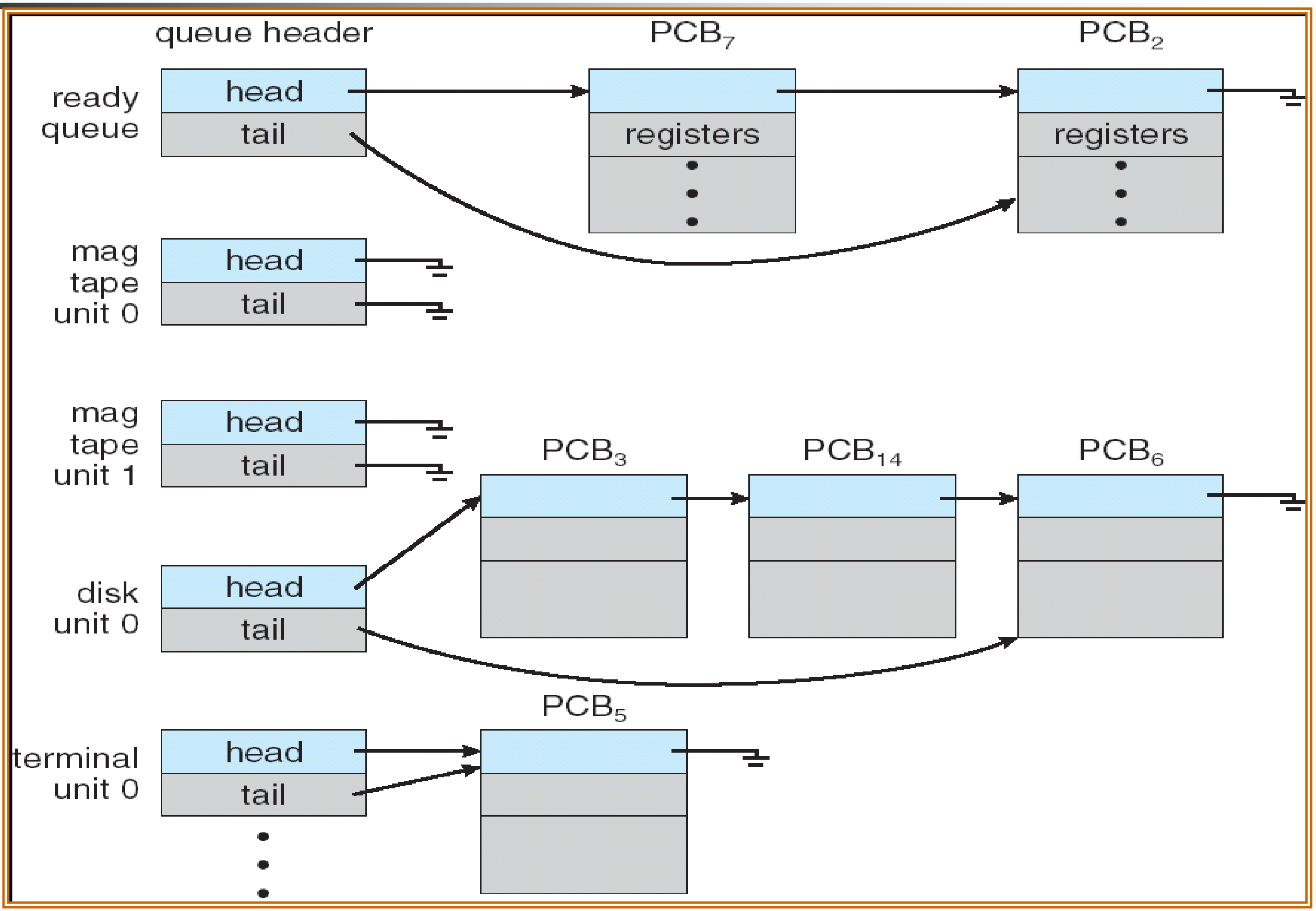
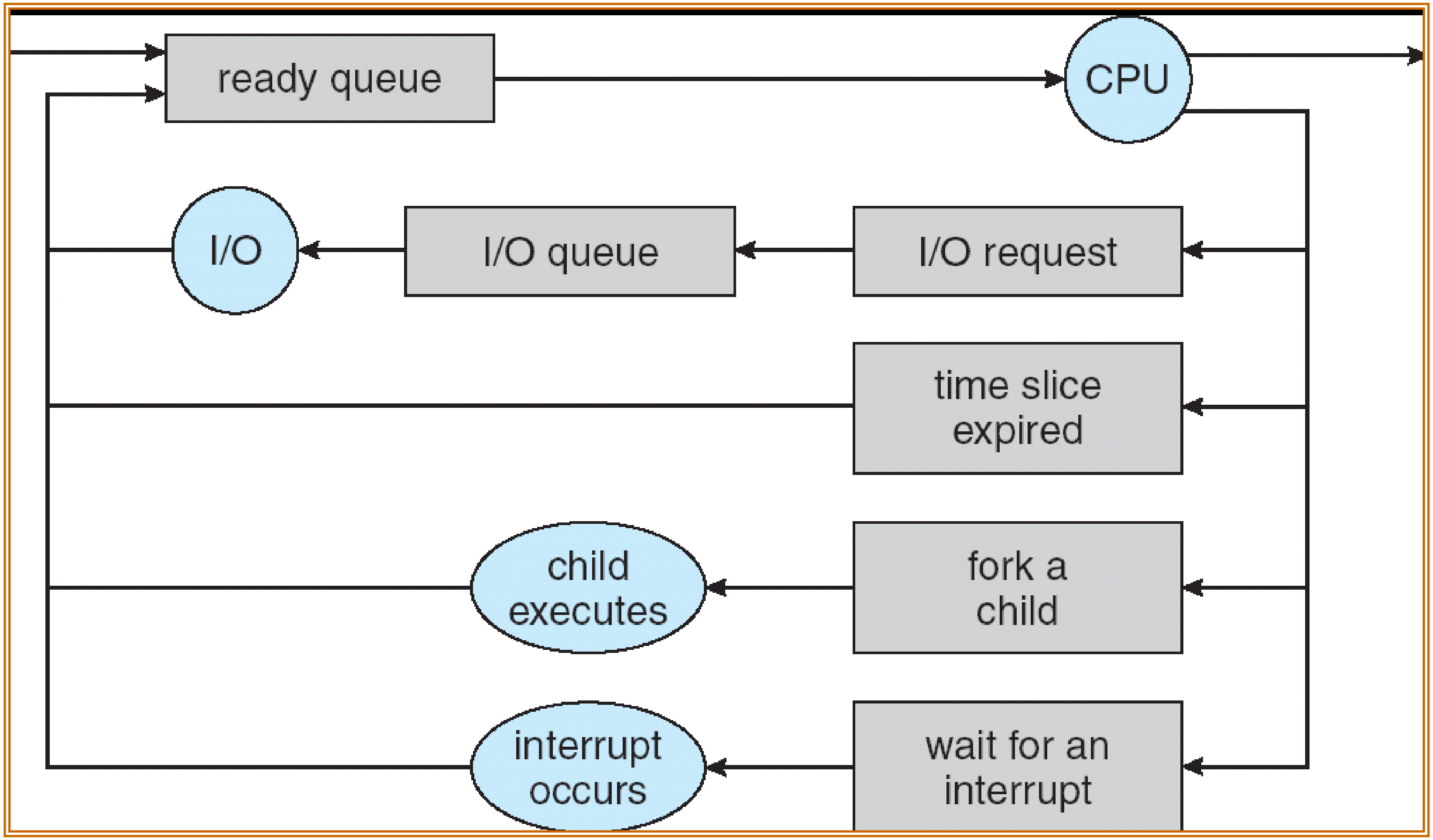
# Process Scheduling Queues

- Job queue – set of all processes in the system
  - Ready queue – set of all processes residing in main memory, ready and waiting to execute
  - Device queues – set of processes waiting for an I/O device
  - Process migration between the various queues

# Ready Queue And Various I/O Device Queues



# Representation of Process Scheduling



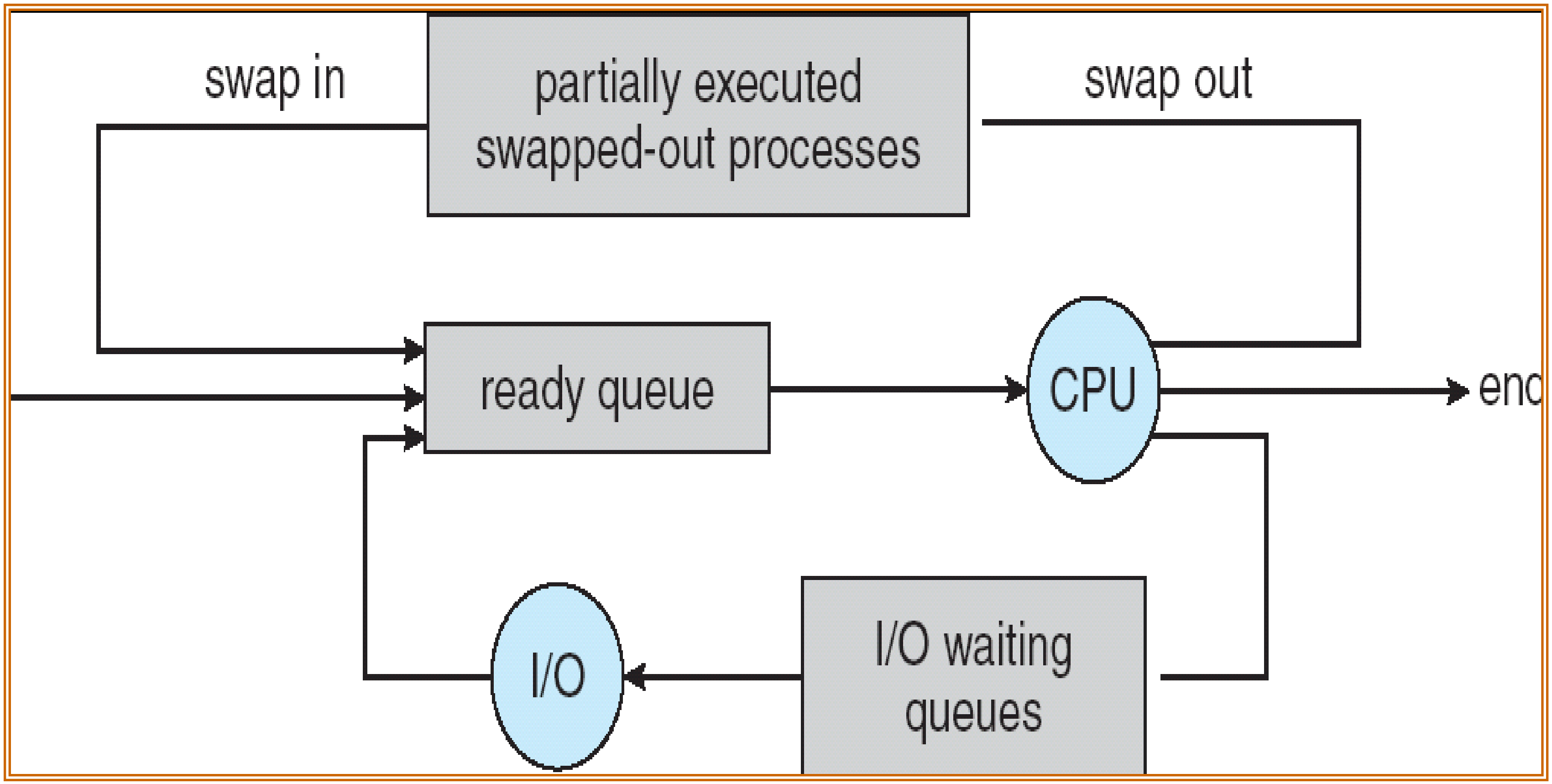
# Schedulers

- **Long-term scheduler (or job scheduler) – selects which processes should be loaded into memory for execution.**
- **Short-term scheduler (or CPU scheduler) – selects which process should be executed next and allocates CPU.**
- **Medium-term scheduler – remove processes from memory and reintroduce them into memory later (swapping).**

# Schedulers

- **Short-term scheduler is invoked very frequently (milliseconds) $\Rightarrow$ (must be fast).**
- **Long-term scheduler is invoked very infrequently (seconds, minutes) $\Rightarrow$ (may be slow).**
- **The long-term scheduler controls the *degree of multiprogramming* *(the number of processes in memory).***

# Medium-Term Scheduling



# Schedulers

- Processes can be described as either
  - *I/O-bound process* – spends more time doing I/O than doing computations.
  - *CPU-bound process* – spends more time doing computations than doing I/O.
- The long-term scheduler select a good process mix of I/O-bound and CPU-bound processes.

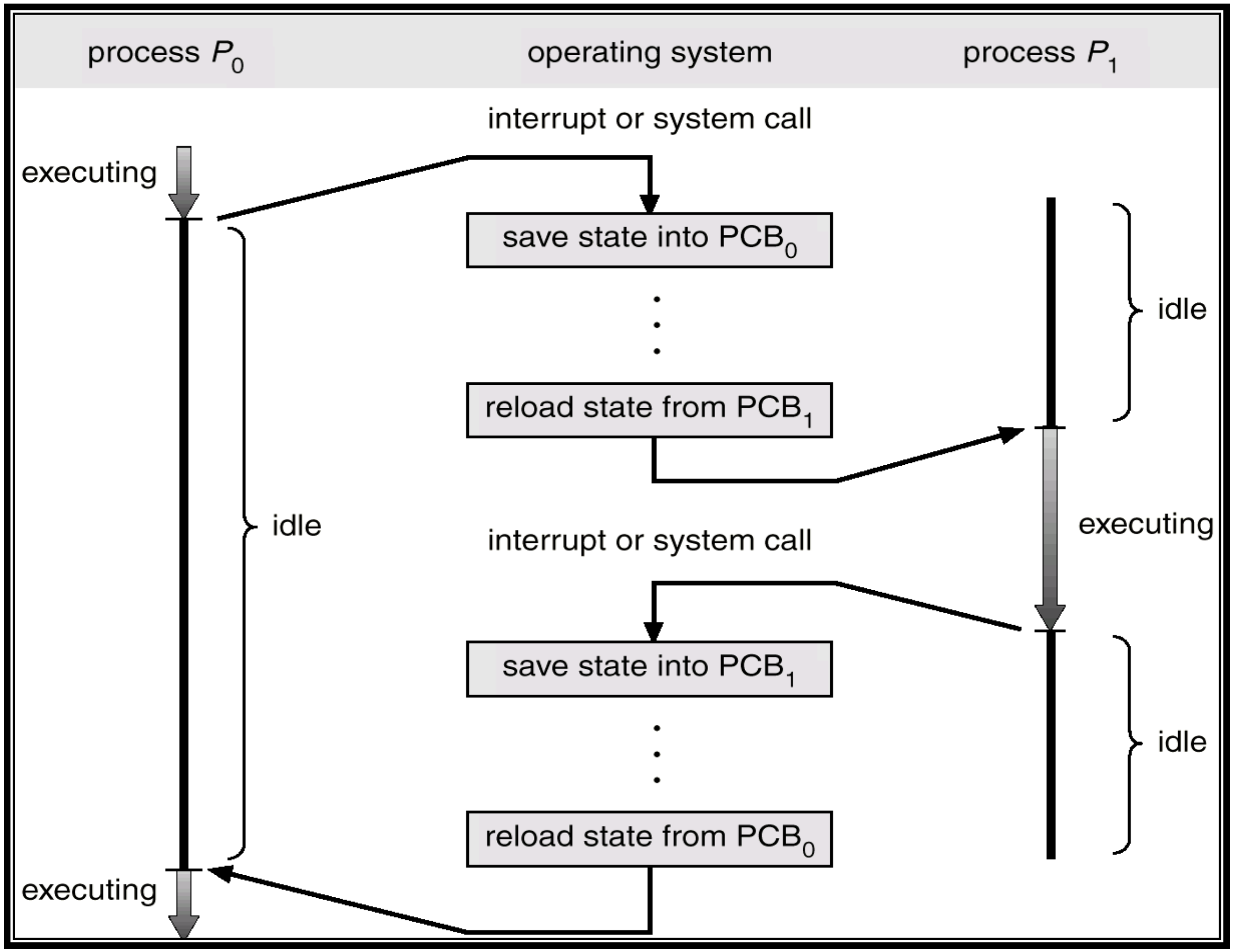
# Context Switch

- What is a process context?
  - The *context* of a process is represented in the PCB of the process and includes the values of CPU registers, the process state, the program counter, and other memory/file management information.

# Context Switch

- When CPU switches to another process, the system must save the state of the old process and load the saved state for the new process.
- Context-switch time is overhead; the system does no useful work while switching.
- Context-switch time dependent on hardware support.

# CPU Switch From Process to Process



# Exercise

- 下列哪一种情况不会引起进程之间的切换？
  - A.进程调用本程序中定义的函数进行计算
  - B.进程处理I/O请求
  - C.进程创建子进程并等待子进程结束
  - D.产生中断

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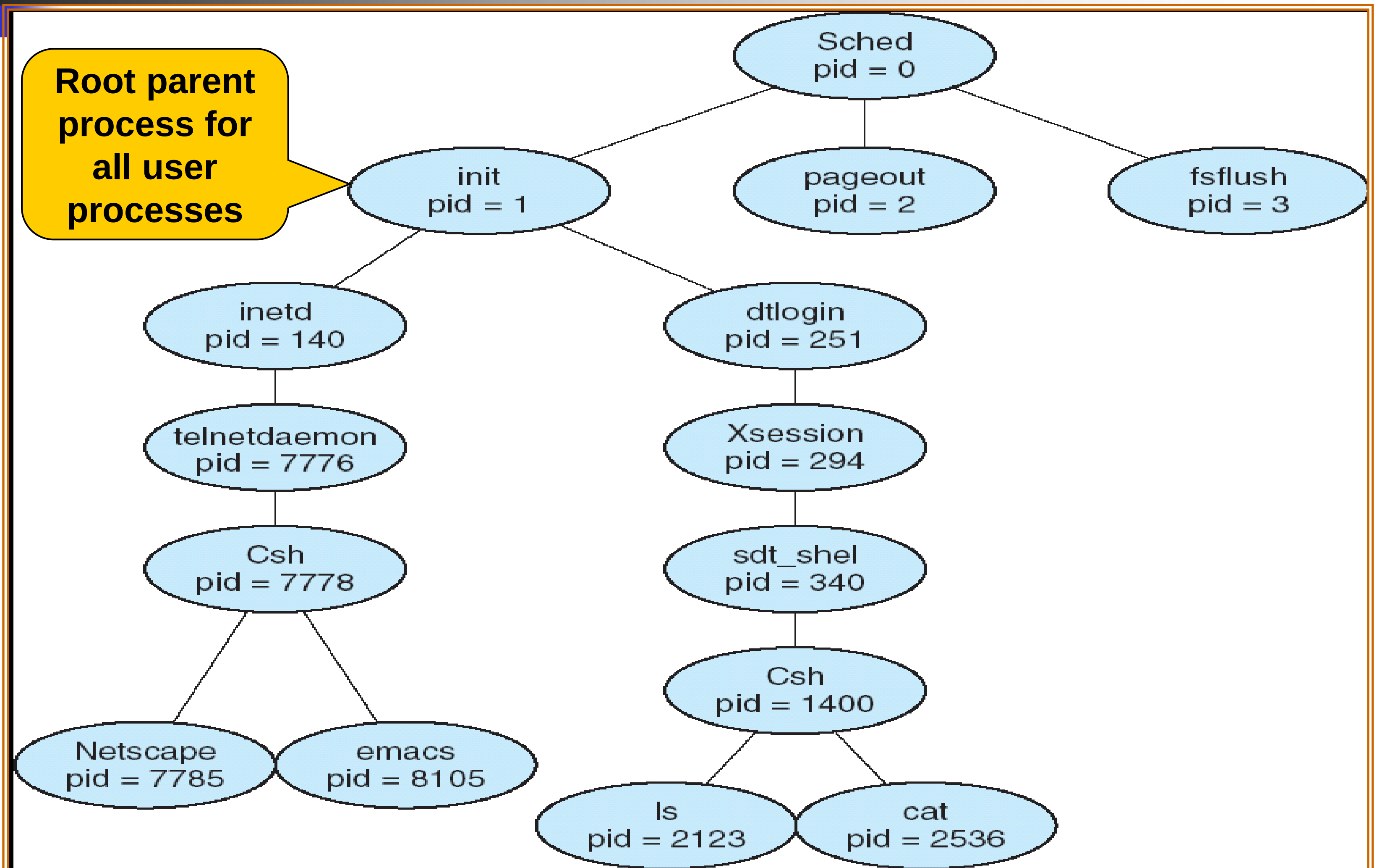
# Process Creation

- **Parent process create children processes, which, in turn create other processes, forming a tree of processes.**
- **A unique process identifier (an integer number) is used to identify process.**

# Processes Tree on Solaris



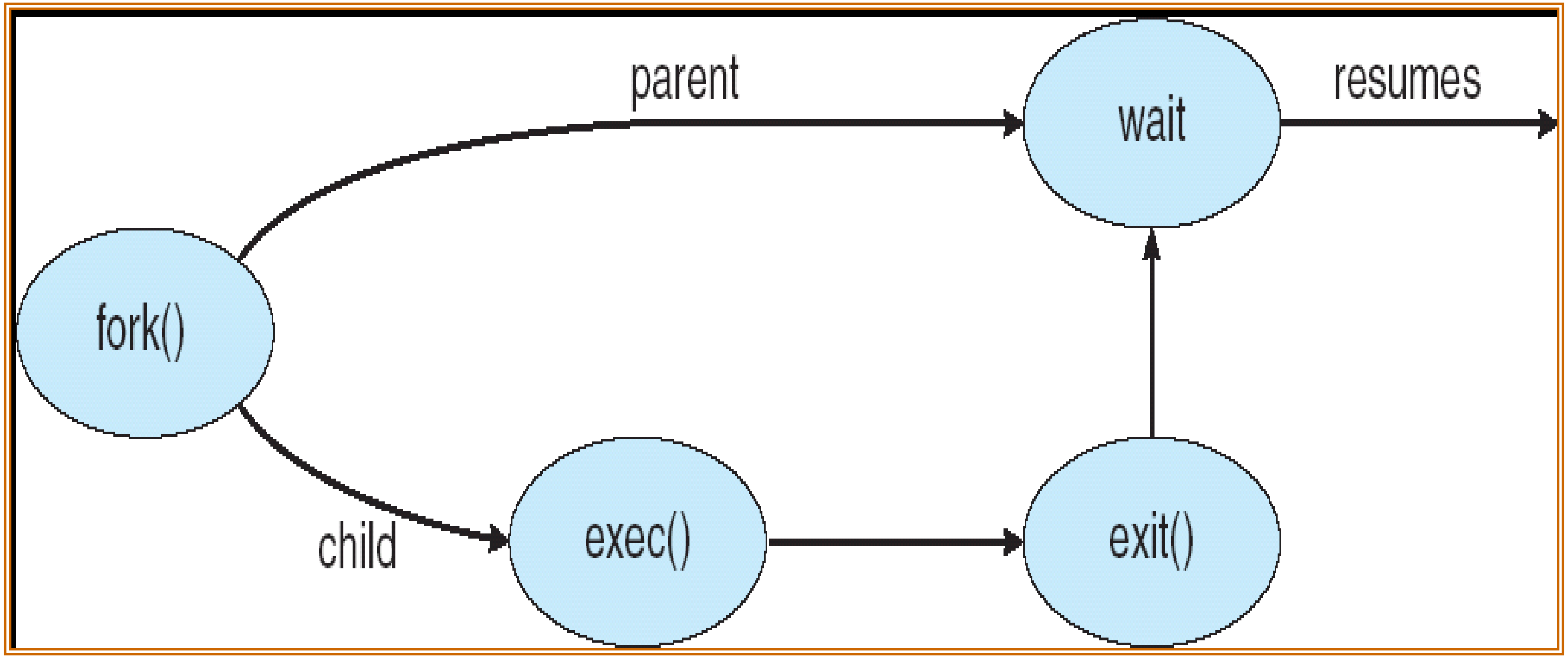
# Process Creation

- Resource sharing
  - Parent and children share all resources.
  - Children share subset of parent's resources.
  - Parent and child share no resources.
- Execution
  - Parent and children execute concurrently.
  - Parent waits until children terminate.

# Process Creation

- **Address space**
  - **Child duplicate of parent.**
  - **Child has a program loaded into it.**
- **UNIX examples**
  - **fork() system call creates new process**
  - **exec() system call used after a fork to replace the process's memory space with a new program.**

# Process Creation (UNIX)



```
pid = fork();
if (pid < 0){/*error occured*/
    fprintf(stderr, “Fork failed”);
    exit(-1);}
else if(pid == 0){/*child process*/
    execlp(“/bin/ls”,”ls”,NULL);
}
else {/*parent process*/
    wait(NULL);
    printf(“Child Complete”);
    exit(0);
}
```

# 作业3

- 下列程序的输出是什么？

```
#include <sys/wait.h>
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
#include <stdlib.h>
int value = 5;
int main()
{  pid_t pid;
   pid = fork();
   if (pid == 0) {   printf("child process, value1 : %d\n", value);
                    value += 15;
                    printf("child process, value2 : %d\n", value);}

    else if (pid > 0) { printf("parent process, value3 : %d\n", value);
                        wait(NULL);
                         printf("parent process, value4 : %d\n", value);
                         exit(0);   }
}
```

# Process Termination

- Process executes last statement and asks the operating system to delete it (exit).
  - Output data from child to parent (via wait).
  - Process's resources are deallocated by OS.

# Process Termination

- Parent may terminate execution of children processes (abort).
  - Child has exceeded allocated resources.
  - Task assigned to child is no longer required.
  - Parent is exiting.（并非所有OS都如此，UNIX）
    - Operating system does not allow child to continue if its parent terminates.
    - Cascading termination (级联终止).

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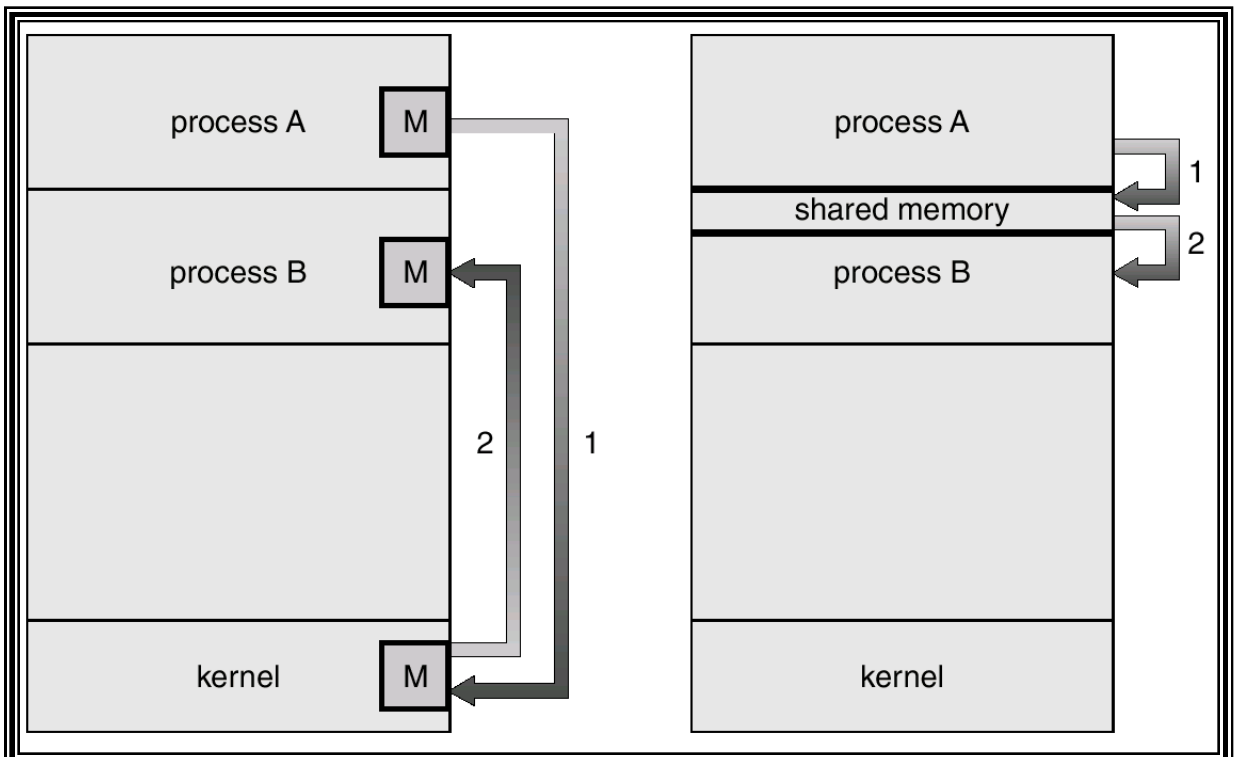
# Interprocess Relationship

- ***Independent*** **process cannot affect or be affected by the execution of another process.**
- ***Cooperating*** **process can affect or be affected by the execution of another process**
- **Advantages of process cooperation**
  - **Information sharing**
  - **Computation speed-up**
  - **Modularity**
  - **Convenience**

# InterProcess Communication (IPC)

- Communication may take place using either **shared memory** or **message passing**.



# Shared-Memory Systems

- Requiring communicating processes to establish a region of shared memory.
- A shared-memory region resides in the address space of the process creating the shared-memory segment.
- The processes are responsible for ensuring that they are not writing to the same location simultaneously.

# Producer-Consumer Problem

- Paradigm for cooperating processes, *producer* process produces information that is consumed by a *consumer* process.
  - *unbounded-buffer* places no practical limit on the size of the buffer.
  - *bounded-buffer* assumes that there is a fixed buffer size.

# Bounded-Buffer – Shared-Memory Solution

- **Shared data**

```
#define BUFFER_SIZE 10
Typedef struct {
  . . .
} item;
item buffer[BUFFER_SIZE];
int in = 0;
int out = 0;
```

# Bounded-Buffer – Producer Process

```
item nextProduced;

while (1) {
        while (((in + 1) % BUFFER_SIZE) == out)
                ; /* do nothing */
        buffer[in] = nextProduced;
        in = (in + 1) % BUFFER_SIZE;
}
```

# Bounded-Buffer – Consumer Process

```
item nextConsumed;

while (1) {
      while (in == out)
            ; /* do nothing */
      nextConsumed = buffer[out];
      out = (out + 1) % BUFFER_SIZE;
}
```

# Discussion

- **Solution is correct, but can only use BUFFER_SIZE-1 elements**

**Why?**

- *如何实现可使用缓冲的最大空间数为 BUFFER_SIZE？*

# Message-Passing Systems

- MPS facility provides two operations:
  - **send(*message*)** – message size fixed or variable
  - **receive(*message*)**
- If P and Q wish to communicate, they need to:
  - establish a ***communication link*** between them
  - exchange messages via send/receive
- Implementation of communication link
  - physical (e.g., shared memory, hardware bus)
  - logical (e.g., logical properties)

# Implementation Questions

- How are links established?
- Can a link be associated with more than two processes?
- How many links can there be between every pair of communicating processes?
- What is the capacity of a link?
- Is the size of a message that the link can accommodate fixed or variable?
- Is a link unidirectional or bi-directional?

# Direct Communication

- Processes must name each other explicitly:
  - send (*P, message*) – send a message to process P
  - receive(*Q, message*) – receive a message from process Q
- Properties of communication link
  - Links are established automatically.
  - A link is associated with exactly one pair of communicating processes.
  - Between each pair there exists exactly one link.
  - The link may be unidirectional, but is usually bidirectional.

# Indirect Communication

- Messages are sent and received from mailboxes (also referred to as ports).
  - Each mailbox has a unique id.
  - Two processes can communicate only if they share a mailbox.
- Properties of communication link
  - Link established only if processes share a common mailbox
  - A link may be associated with many processes.
  - Each pair of processes may share several communication links.
  - Link may be unidirectional or bidirectional.

# Indirect Communication

- Operations
  - create a new mailbox
  - send and receive messages through mailbox
  - destroy a mailbox
- Primitives are defined as:

**send(*A, message*) – send a message to mailbox A**

**receive(*A, message*) – receive a message from mailbox A**

# Indirect Communication

- Mailbox sharing
  - $P_1$, $P_2$, and $P_3$ share mailbox A.
  - $P_1$, sends; $P_2$ and $P_3$ receive.
  - Who gets the message?
- Solutions
  - Allow a link to be associated with at most two processes.
  - Allow only one process at a time to execute a receive operation.
  - Allow the system to select arbitrarily the receiver. Sender is notified who the receiver was.

# Synchronization

- **Message passing may be either blocking or non-blocking.**
- **Blocking is considered synchronous**
- **Non-blocking is considered asynchronous**
- **send and receive primitives may be either blocking or non-blocking.**

# Buffering

- Queue of messages attached to the link implemented in one of three ways.
  - Zero capacity – 0 messages.
    Sender must wait for receiver.
  - Bounded capacity – finite length of *n* messages.
    Sender must wait if link full.
  - Unbounded capacity – infinite length.
    Sender never blocks.

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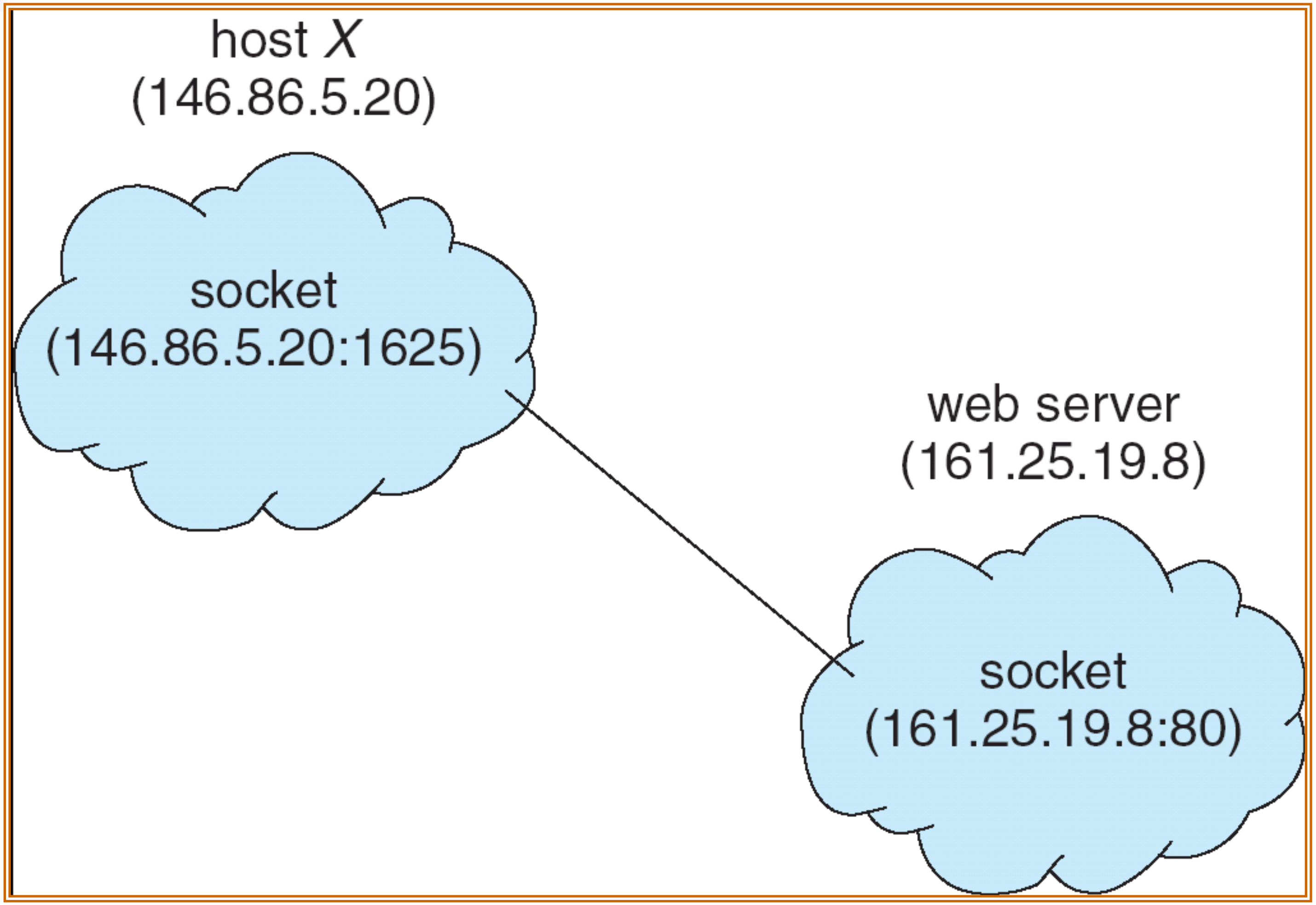
# Client-Server Communication

- **Sockets**
- **Remote Procedure Calls**
- **Remote Method Invocation (Java)**

# Sockets

- A socket is defined as an ***endpoint for communication***.
- Concatenation of IP address and port
- The socket 161.25.19.8:1625 refers to port 1625 on host 161.25.19.8
- Communication consists between **a pair of sockets**.

# Socket Communication



# Socket Communication

- All connections must be unique.
- Common and Efficient
- A low-level form of communication between distributed processes
- Sockets allow only an unstructured stream of bytes to be exchanged between the communicating processes.

# Remote Procedure Calls

- **Remote procedure call (RPC) abstracts procedure calls between processes on networked systems.**
- **RPC allow a client to invoke a procedure on a remote host as it would invoke a procedure locally.**
- **Stubs – client-side proxy for the actual procedure on the server.**
- **Each message exchanged contains an identifier of the function and the parameters to pass to it.**

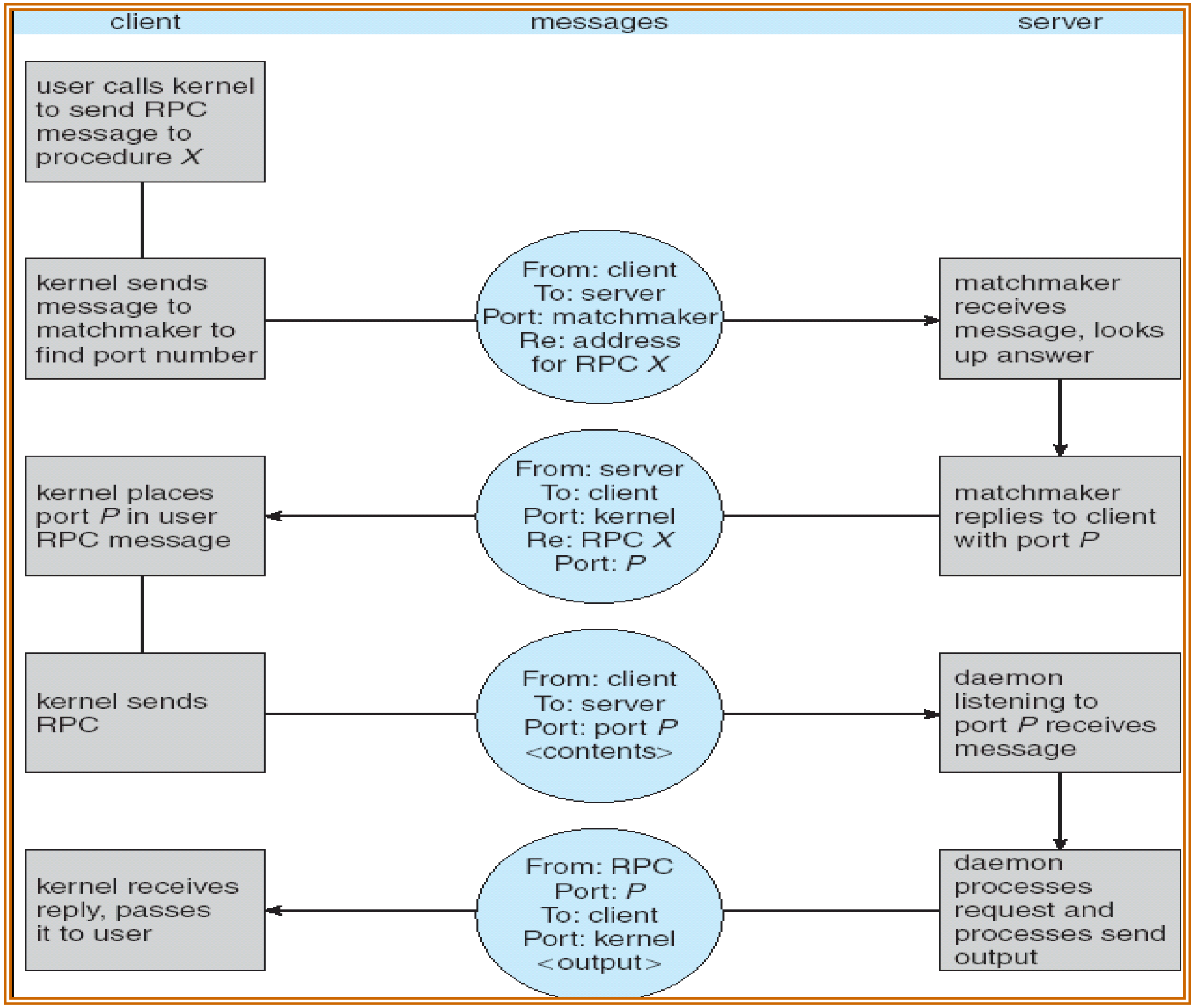
# Remote Procedure Calls

- The client-side stub locates the port on the server and *marshals* the parameters.
- The server-side stub receives this message, unpacks the marshaled parameters, and performs the function on the server.
- Any output is send back to the requester in a separate message.
- Messages exchanged in RPC communication are well structured.

# Remote Procedure Calls

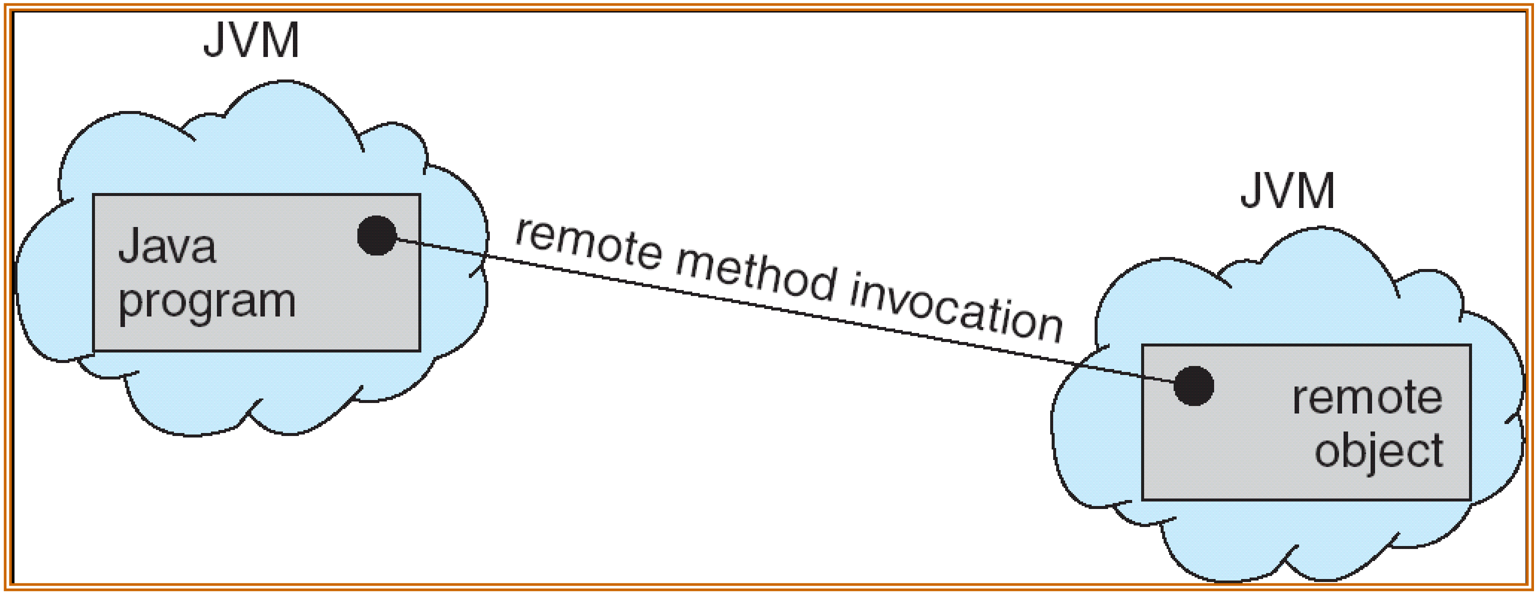
- Some Issues
  - The differences in data representation on the client and server machines.
    - eXternal Data Representation (XDR)
  - The semantics of a call
    - Exactly once（lost？）: ACK Messages
    - At most once（repeated?）: attaching a timestamp to each message.

# Execution of RPC



# Remote Method Invocation

- Remote Method Invocation (RMI) is a Java mechanism similar to RPCs.
- RMI allows a Java program on one machine to invoke a method on a remote object.



# Remote Method Invocation

- Differences between RPC and RMI
  - RPC only calls remote procedures or functions, and RMI supports invocation of methods on remote objects
  - The parameters to remote procedures are ordinary data structures in RPC, and that are objects in RMI

# Remote Method Invocation

- RMI implements the remote object using stubs and skeletons.
  - Stub is a proxy for the remote object and resides with the client.
  - Skeleton resides with the server, receives the messages from stub and invokes the desired method on the server.

# Marshalling Parameters